Absence of deterioration of vascular function of the donor limb at late follow-up after radial artery harvesting

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Objective: Radial artery harvesting has been questioned because of purported long-term circulatory consequences. Previous midterm Doppler ultrasonographic results are inconsistent regarding ulnar arterial effects. Flow-mediated vasodilatation more sensitively measures response to shear stress as index of arterial reactivity and function.

Methods: We contacted 231 patients who had undergone radial artery harvesting at least 10 years previously (mean follow-up, 12.9 ± 0.8 years). Subcohort of 25 volunteers (mean age, 69.2 ± 8.4 years) underwent ultrasonographic evaluation of ipsilateral (harvest) and contralateral (control) ulnar arteries. Flow-mediated vasodilatation compared changes in ulnar arterial diameters before and after occlusion.

Results: In subcohort, peak systolic velocity of harvest ulnar artery was 0.82 ± 0.15 m/s, versus 0.63 ± 0.23 m/s on control side ($P < .001$), with no differences in intimomedial thickness ($P = .763$) or presence of atherosclerotic plaques ($P = .364$). Baseline diameter of harvest ulnar artery was 3.0 ± 0.5 mm, versus 2.7 ± 0.6 mm on control side ($P = .007$). Postocclusion diameter of harvest ulnar artery was 3.2 ± 0.5 mm, versus 2.9 ± 0.6 mm on control side ($P = .001$). No differences were seen in preocclusion and postocclusion absolute and percentage changes in ulnar arterial diameter (Table 1).

Conclusions: Despite increased shear stress, no deterioration in either ulnar arterial structure or functional reactivity was measured by flow-mediated vasodilatation more than 10 years after radial artery harvesting. With appropriate preoperative evaluation, radial arterial grafting for coronary artery bypass grafting is not associated with long-term donor limb vascular insufficiency. (J Thorac Cardiovasc Surg 2011;142:298-301)

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The radial artery (RA) has been widely used as a conduit for coronary artery bypass grafting for more than 2 decades and is considered by some to be second in preference only to the internal thoracic artery (ITA). The ability to harvest the RA without ischemic compromise to the hand is based on the collateral circulation provided by the ulnar artery (UA), which is assessed by the Allen test. Fortunately, hand ischemia is extremely rare despite harvesting the entire length of the RA. Since its first use, RA harvesting has been questioned because of purported long-term circulatory consequences. The issue of the long-term circulatory status of the hand and forearm after radial harvest is unknown and therefore must be of concern to all. Only 2 reports have addressed the late status of the UA, and their results are inconsistent.[1,2] In these studies, the UA was evaluated with ultrasonography to measure blood flow, diameter, intimomedial thickness (IMT), and the presence of atheroma. One of them found a greater number of atheroma and increased IMT and suggested that increased flow in the UA after RA harvest was responsible and could eventually result in flow-compromising atherosclerosis.[1] This conclusion has obvious implications for long-term vascularization of the limb, particularly in younger patients. All the most relevant studies to date, however, have exclusively reported ultrasonographically gathered information.

Flow-mediated vasodilatation (FMD) is considered a more sensitive measure of the response to shear stress and serves as an index of arterial reactivity and function. To date, there are no data regarding FMD in the UA after RA harvest. The aim of this study was to examine FMD data to provide insight into UA status nearly 13 years after RA harvest.

MATERIALS AND METHODS

Patient Population

Data from 231 patients who had undergone RA harvesting more than 12 years previously (mean follow-up, 12.9 ± 0.8 years) were collected retrospectively and by phone interview. A subcohort of 25 volunteers underwent ultrasonographic evaluation of the ipsilateral (harvest) and the contralateral (control) UAs, as well as of the remaining RA and the brachial arteries. Negative results of the Allen test (capillary return to the palm and thumb by 12 seconds) preceded RA harvest.[3] If skin pigmentation precluded visual assessment, a digital oximeter was placed on the thumb to record return of a wave form and oxygenation. This study received approval by the institutional review board of Washington University in St Louis. Patient demographic data and risk factors are reported in Table 1.

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Abbreviations and Acronyms
FMD = flow-mediated dilatation
IMT = intimomedial thickness
ITA = internal thoracic artery
RA = radial artery
UA = ulnar artery

Flow-Mediated Dilatation

The FMD test was performed as previously described.[4] This technique has been widely used to assess vascular health and physiologic responsiveness in many circumstances. Briefly, each of the 25 patients in the volunteer subcohort was electively scheduled for a bilateral arterial ultrasonographic evaluation of the forearm. They were instructed to fast for at least 8 hours and to discontinue any vasoactive medication (β-blockers, calcium-channel blockers, angiotensin receptor inhibitors, and nitrates) the night before the test. In a dedicated vascular laboratory room at 23°C with the patient supine, a blood-pressure cuff was applied above the antecubital fossa and a baseline rest image of the UA was obtained by Doppler ultrasonography, which provided clear views of the anterior and posterior intimal interfaces. The cuff was then inflated to 50 mm Hg above the systolic blood pressure for a standardized time (5 minutes) to create a flow stimulus. This induces local ischemia and dilation of downstream resistance vessels through autoregulatory mechanisms. The subsequent cuff deflation, inducing brief high-flow state (reactive hyperemia and increased shear stress) to accommodate the dilated resistance vessels, preceded the next imaging evaluation. Peak velocity and vessel diameter were measured within 30 seconds after cuff deflation (postocclusion). A 10-minute rest was allowed before acquisition of the next image, reflecting reestablished baseline conditions. This cycle was repeated for each vessel studied: control and harvest UAs, control and harvest brachial arteries, and control RA. The length of the UA was scanned for atheromas and calcification. Atheromas were defined as local intimal thickenings. Echogenic foci in the arterial wall with posterior acoustic shadowing were recognized as calcification in the media. Calcification in atheromas was not seen. Ultrasonography also allowed measurement of IMT. Change in IMT in the carotid artery has been used as an index of atherosclerosis generally. All measurements were an average of 3 cardiac cycles. FMD was measured by comparing the change in UA diameter before and after occlusion.

Statistical Analysis

Descriptive statistics are expressed as mean ± SD unless otherwise specified. Categoric data are expressed as counts and proportions. Comparisons were performed with 2-tailed *t* tests for means of normally distributed continuous variables. All data analysis was performed with SPSS statistical software (SPSS 11.0 for Windows; SPSS Inc, an IBM Company, Chicago, Ill).

RESULTS

The patients who volunteered for the study were representative of the long-term follow-up group. Most patients were male and had a history of hypertension, hypercholesterolemia, and tobacco use (Table 1). The average age at surgery was 57 years, and the mean follow-up time was 12.9 years. Peak systolic velocity in the donor UA was significantly higher (0.82 ± 0.15 m/s vs 0.63 ± 0.23 m/s, $P < .001$) than in the control UA, whereas basal measurements were similar in the 2 arteries. No difference in end-systolic velocity was found between the two groups. The IMTs were similar between groups ($P = .763$) which was also true for atheroma ($P = .364$) and medial calcification ($P = .754$; Table 2).

TABLE 1. Patients demographic characteristics and risk factors

Variable	Value
Male (no.)	21 (84%)
Mean age at surgery (y, mean ± SD)	57.0 ± 8.7
Mean age at study (y, mean ± SD)	68.6 ± 8.4
Mean time from surgery to study (y, mean ± SD)	12.9 ± 0.8
Cardiac risk factors (no.)	
Hypertension	16 (64%)
Diabetes	7 (16%)
Hypercholesterolemia	15 (60%)
Smoker (past)	11 (44%)
Smoker current (at surgery)	10 (40%)
Smoker current (at study)	5 (20%)

The baseline diameter of the harvest UA was significantly greater than that of the control UA (3.0 ± 0.5 mm vs 2.7 ± 0.6 mm, $P = .007$). Postocclusion diameters were similarly different (3.2 ± 0.5 mm vs 2.9 ± 0.6 mm, $P = .001$). As shown in Table 3, however, in a comparison of preocclusion and postocclusion absolute and percentage changes in UA diameters, no significant differences were found.

DISCUSSION

During the last 4 decades, coronary artery bypass grafting emerged as one of the leading treatments of severe, multivessel coronary artery disease. Although it has declined in frequency as percutaneous intervention has flourished, coronary artery bypass grafting will continue to be needed in the future. It is important that the most durable conduits be used to achieve long-term patency, because the benefit of either type of revascularization persists only as long as the stent or graft remains patent.

The search for suitable conduits has been reported extensively. It is clear now that the saphenous vein graft deteriorates with time, and its occlusion rate reaches as high as 50% at 10 years after coronary artery bypass grafting, mainly as a result of atherosclerosis in the graft. The ITA graft, in contrast, has very good long-term patency, which directly relates to its superior outcome in terms of longevity and postoperative cardiac events.[5] In the 1970s, some predicted that the ITA would have accelerated arteriosclerosis because of the stressful nature of the coronary circulation, when in fact this was true of the saphenous vein. Rather, the ITA has proved itself with regard to patency and freedom from late atherosclerosis.[6]

The RA has gained increased popularity as an alternative arterial conduit for coronary artery bypass grafting. Ten-year patency data for the RA are now appearing, and at 83% the rate is clearly better than historical data for saphenous vein grafts.[7,8] Although this rate is inferior to the ITA patency rate, neither of these conduits is known to become

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TABLE 2. Flow-mediated vasodilation and vessel characteristics

Location	Peak systolic velocity (m/s)	End systolic velocity (m/s)	Resistance index	Intimal medial thickness (mm)	Calcification (no.)	Atherosclerotic plaques (no.)
Brachial artery						
Control	0.86 ± 0.19	0.02 ± 0.03	0.98 ±0.03	0.51 ± 0.14	2 (8%)	3 (12%)
Harvest	0.83 ± 0.21	0.03 ± 0.04	0.93 ± 0.18	0.48 ± 0.22	1 (4%)	2 (8%)
P value	.297	.210	.202	.592	>.999	>.999
Radial artery						
Control	0.68 ± 0.18	0.06 ± 0.06	0.91 ±0.08	0.44 ± 0.14	6 (24%)	6 (24%)
Ulnar artery						
Control	0.63 ± 0.23	0.06 ± 0.06	0.92 ± 0.07	0.47 ± 0.18	8 (32%)	10 (40%)
Harvest	0.82 ± 0.15	0.07 ± 0.07	0.92 ± 0.08	0.48 ± 0.18	6 (24%)	6 (24%)
P value	<.001	.612	.947	.763	.754	.364

Values are mean ± SD except when noted to be numbers of patients.

atherosclerotic. RA harvest does pose the risk of forearm ischemia, however, both early if ulnar collateral flow is inadequate and late should the UA become insufficient. It has been reported that RA harvest is associated with immediate increases in UA flow and diameter. This would happen through an early phase of flow-mediated vasodilatation (10%–15% maximum increase in arterial diameter) and a late phase characterized by both arterial remodeling and return of peak wall shear stress nearly to baseline values.[9] Similarly, uremic patients undergoing creation of a forearm arteriovenous fistula have a 6- to 32-fold increase in RA blood flow (as opposed to the 2- to 3-fold increase in UA flow after RA harvest) and an increase in RA diameter from 2.4 to 4.4 mm in the course of 100 days, with a return of peak wall shear stress to control levels.[10] No increase in IMT has been observed.

Gaudino and coworkers[1] evaluated the effect of RA harvesting on the UA flow 10 years later in 25 patients. They observed no significant increase in UA diameter despite chronic increase in flow and, rather significant increase in peak systolic flow velocity and wall shear stress with coexisting increase in IMT, and new atheroma formation. Their inference was in favor of potential impairment of blood flow to the hand and forearm due to accelerated atherosclerosis. A second report of 85 patients at a mean follow-up of 8.4 years after RA harvest found no new atheroma and increases in both UA diameter and flow relative to control values (111 mL/min vs 59 mL/min, $P < .001$).[2]

Both these studies were exclusively based on Doppler ultrasonographic imaging to assess flow characteristics, artery diameters, and wall structure. Such technique provides valuable hemodynamic and structural information, as well as documenting the absence or presence of arterial remodeling. Remodeling is a normal physiologic response to changes in blood flow with time. We have also used FMD, a technique developed in the early 1990s, to assess endothelium-dependent flow-mediated response of the UA to shear stress–stimulated endothelial release of nitric oxide. The resulting vasodilation can be quantitated as an index of endothelial function and of the response of the medial smooth muscle to a physiologic stimulus.[11] Importantly, brachial artery FMD was inversely associated with carotid artery IMT.[12]

We observed that both harvest and control UAs had similar function. Our anatomic data support the observations of Royse and associates,[2] with documentation of UA remodeling and absence of either atheroma formation or an increase of IMT contrary to the findings of Gaudino and coworkers.[1] In addition, our interval of observation was 12.9 ± 0.8 years, versus 8.2 ± 1.0 years and 10 years.

One limitation of our study is represented by the use of ultrasonography, which is operator dependent, to evaluate small vessels anatomically and physiologically. Technical skills are developed by training and by practice with supervision to create the standardization and consistency that are seen in highly experienced vascular laboratories. Measurement of FMD has been used for nearly 2 decades in some institutions and for more than a decade in our own. The same 2 certified technicians performed these studies.

Our data support continued use of the RA as a bypass conduit. We do not find evidence for accelerated vascular wall disease, nor for vascular dysfunction in the remaining

TABLE 3. Preocclusion and postocclusion ulnar artery diameter measured by flow-mediated dilatation

	Baseline diameter (mm)	Post–flow-mediated dilatation diameter (mm)	Change (%)	*P* value	Absolute Change (mm)	*P* value
Control	2.71 ± 0.60	2.85 ± 0.58	5.8% ± 1.5%	.747	0.14% ± 0.17%	.313
Harvest	3.00 ± 0.45	3.18 ± 0.47	6.4% ± 1.1%		0.19% ± 0.14%	

Values are mean ± SD.

UA. The behavior of the UA after RA harvest is consistent with the behavior of harvested conduits.[13] As has been suggested, there is little reason to believe that the UA has behaved or will behave differently.[14]

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